1. Course Information					
1.1	**Course Name:**	Machine Learning	**1.2**	**Course Code:**	EC332
1.3	**Credit Hours:**	3	**1.4**	**Contact Hours:**	3
1.5	**Pre-requisites:**	Probability and Statistics, Linear Algebra			
1.6	**Course Introduction:** The ability of biological brains to sense, perceive, analyse and recognise patterns can only be described as stunning. Furthermore, they have the ability to learn from new examples. Mankind's understanding of how biological brains operate exactly is embarrassingly limited. However, there do exist numerous 'practical' techniques that give machines the 'appearance' of being intelligent. This is the domain of statistical pattern recognition and machine learning. Instead of attempting to mimic the complex workings of a biological brain, this course aims at explaining mathematically well-founded techniques for analysing patterns and learning from them. This course is a mathematically involved introduction into the wonderful world of Machine Learning. It will prepare students for further study/research in the areas of Pattern Recognition, Computer Vision, Data Analysis, Natural Language Processing, Speech Recognition, Machine Translation, Autonomous Driving and other areas attempting to solve Artificial Intelligence (AI) type problems. Machine learning is one of the fastest growing areas of computer science, with far-reaching applications. The aim of this course is to: a) Present the basic machine learning concepts; b) Present a range of machine learning algorithms along with their strengths and weaknesses; c) Apply machine learning algorithms to solve problems of moderate complexity.				
1.7	**Course Outline:** Introduction to machine learning; Probability distributions, ML and MAP estimation; Supervised learning, linear regression, logistic regression, neural networks, loss functions, gradient descent, automatic differentiation, regularization; Ensemble learning; Unsupervised clustering, non-parametric density estimation, clustering, principal component analysis; Semi-supervised learning, mixture				

	models, EM algorithm, adversarial learning; Reinforcement learning, bandit problem, Markov decision processes, dynamic programming, Monte Carlo methods, temporal-difference learning; Learning on sequences, transformers
1.8	**Additional Content:**

2. Unit-wise Major Topics

2.1	**Unit No.**	**2.2 Topic Course Outline divided into topics**	**2.3 Teaching Hours**
2.1.1	**U1**	Introduction to Machine Learning	3
2.1.2	**U2**	Probability Distributions	6
2.1.3	**U3**	Supervised Learning	10.5
2.1.4	**U4**	Ensemble Learning	1.5
2.1.5	**U5**	Unsupervised Learning	6
2.1.6	**U6**	Semi-supervised Learning	6
2.1.7	**U7**	Reinforcement Learning	9
2.1.8	**U8**	Learning on Sequences	3
		Total Teaching Hours:	**45**

3. Mapping of each Course Learning Outcomes (CLOs) to (a) Unit Nos., (b) Bloom's Taxonomy, and (c) Program Level Outcomes (PLOs).

3.1	**CLO No.**	**3.2 Course Learning Outcomes (CLOs) Description**	**2.1 Unit No.**	**3.3 Bloom's Taxonomy**	**3.4 PLOs**
		3.1.1 CLOs for Theory			
3.1.1.1	CLO-1	Describe basic machine learning concepts, theories and applications.	U1-U2	C1 (Knowledge)	1-3
3.1.1.2	CLO-2	Apply supervised, unsupervised and semi-supervised learning techniques to solve classification problems of moderate complexity.	U3-U6	C3 (Apply)	2-5
3.1.1.3	CLO-3	Apply reinforcement learning algorithms to environments with complex dynamics.	U7	C3 (Apply)	2-5

3.1.1.4	CLO-4	Apply transformers to solve sequence to sequence problems of moderate complexity	U8	C3 (Apply)	2-5
3.1.1.5	CLO-5	Develop a reasonable size project using suitable machine learning technique.	U1-U8	C6 (Create)	2-7
3.1.2 CLOs for Lab					

4. CLO Assessment Mechanism

		3.1.1 CLOs for Theory				
		3.1.1.1	**3.1.1.2**	**3.1.1.3**	**3.1.1.4**	**3.1.1.5**
4.1	**Assessment Tools**	**CLO-1**	**CLO-2**	**CLO-3**	**CLO-4**	**CLO-5**
4.1.1	**Quiz**	Quiz 1,2	Quiz 3,4	Quiz 5	Quiz 6	
4.1.2	**Assignment**	Assignment 1	Assignment 2	Assignment 3		
4.1.3	**Project**					Project 1
4.1.4	**Mid-term Exam**	Mid-Term Exam	Mid-Term Exam			
4.1.5	**Final-term Exam**	Final-term Exam				

5. Reading Material

5.1	**Textbook:**	1. Deep Learning: Foundations and Concepts, Christopher Bishop and Hugh Bishop, Springer, 2024.
5.2	**Reference Books:**	1. Machine Learning: A Probabilistic Perspective, Kevin P. Murphy, MIT Press, 2022.
		2. Reinforcement Learning: An Introduction, 2nd Edition, Richard S. Sutton and Andrew G. Barto, MIT Press, 2018.
		3. Data Mining and Machine Learning: Fundamental Concepts and Algorithms, 2nd Edition, Mohammed J. Zaki, Wagner Meira, Jr., Cambridge University Press, 2020.

6. Lecture-wise Plan				
6.1	**2.1**	**6.2**	**6.3**	**6.4**
Lecture No.	**Unit No.**	**Topics Covered**	**Reading Material**	**Quiz / Assign. / H.W. / Project**
1.	**U1**	Introduction to Machine Learning	Bishop 1.1-1.2	
2.	**U1**	Brief History of Machine Learning	Bishop 1.3	
3.	**U2**	Rules of Probability	Bishop 2.1	
4.	**U2**	Probability Densities	Bishop 2.2	Quiz 1
5.	**U2**	Gaussian Distribution	Bishop 2.3, 3.2	
6.	**U2**	Discrete Random Variables	Bishop 3.1	Assignment 1
7.	**U3**	Linear Regression	Bishop 4.1	
8.	**U3**	Logistic Regression	Bishop 5.4.3, 5.4.4	Quiz 2
9.	**U3**	Neural Networks	Bishop 6.3	
10.	**U3**	Loss Functions for Machine Learning	Bishop 6.4	
11.	**U3**	Gradient Descent	Bishop Ch 7	
12.	**U3**	Automatic Differentiation	Bishop 8.2	Quiz 3
13.	**U3**	Regularization	Bishop Ch 9	Assignment 2
14.	**U4**	Boosting	Murphy 18.5.3	
15.	**U5**	Non-parametric Density Estimation	Bishop 3.5	
16.	**U5**	K-Means Clustering	Bishop 15.1	
17.	**Mid-term Exam**			
18.				
19.	**U5**	DBSCAN	Zaki 15.1	Project 1
20.	**U5**	Principal Component Analysis	Bishop 16.1	
21.	**U6**	Gaussian Mixture Models	Bishop 15.2	Assignment 3
22.	**U6**	Expectation-Maximization (EM) Algorithm	Bishop 15.3	Quiz 4
23.	**U6**	EM as a Variational Algorithm	Bishop 15.4	
24.	**U6**	Generative Adversarial Networks	Bishop Ch 17	
25.	**U7**	Reinforcement Learning	Sutton Ch 1	
26.	**U7**	Bandit Problem	Sutton Ch 2	

27.	**U7**	Markov Decision Processes	Sutton Ch 3	Quiz 5
28.	**U7**	Dynamic Programming	Sutton Ch 4	Assignment 4
29.	**U7**	Monte Carlo Methods	Sutton Ch 5	
30.	**U7**	Temporal-Difference Learning	Sutton Ch 6	
31.	**U8**	Transformers	Bishop 12.1	Quiz 6
32.	**U8**	Transformer Language Models	Bishop 12.2, 12,3	
Final-term Exam				